

Acoustical Performance of Noise Barriers

**Highway 401, Between Keele
and Dufferin Streets**



Ontario

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Acoustical Performance of Noise Barriers

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ABSTRACT

This report presents an evaluation of the acoustical performance of highway noise barriers erected on opposite sides of Highway 401, between Keele and Dufferin Streets.

The average barrier insertion loss measured in the backyards adjacent to the barriers was about 6 to 8 dBA. Sound level reductions behind one or two rows of houses were approximately 2 to 3 dBA. A good agreement was obtained between the average measured and the average predicted insertion losses.

Sound level measurements indicated that the construction of the north-side barrier had no adverse effects on the sound levels measured on the south side of the highway.

No definite difference between the acoustical effectiveness of Evercrete and steel barrier materials could be determined due to the statistically insignificant differences in barrier performance.

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1/ INTRODUCTION

This report is one of a series of reports (such as References 1 and 2) which evaluate the acoustical performance of the highway noise barriers constructed by the Ministry of Transportation and Communications (MTC) along Hwy 401. The noise barriers evaluated herein are situated on opposite sides of Highway 401, between Keele and Dufferin Streets. The noise barriers were erected during the summer of 1981. Figure 1 shows the general setting of the site and the location, height, and materials of the two opposing barriers. Also shown are the locations of the measurement points.

The south-side barrier is approximately 525 m long and has the alignment shown in Figure 1. The barrier has a height of 4 m above ground and is constructed of Evercrete panels [3] placed between steel posts.

The north-side barrier consists of three sections and is approximately 1800 m in length. The section adjacent to Keele Street is 4 m above ground and is constructed of Evercrete panels with concrete support posts. This section runs along the highway right-of-way. An overlapping section runs along the edge of the westbound collector lanes. The centre section of the north-side barrier is constructed of Evercrete panels placed in steel support posts and attached to the concrete retaining wall. Along the highway, the barrier was built to a height of 3 m above the pavement. The remainder of the north-side barrier is constructed of steel panels and runs along the highway right-of-way. This section is 4 m in height. At the east end, the north-side barrier is split into two overlapping sections -- one section is along the right-of-way and the other is along the edge of the westbound collector lanes.

2/ MEASUREMENT OF BARRIER INSERTION LOSS

Before- and after-construction sound level measurements were performed at 15 observation points behind the north-side barrier, and at seven points behind the south-side barrier. The observation points were located as shown in Figure 1. The method used to determine the measured barrier insertion loss at each observation point is briefly outlined below.

The before-construction sound level measurements on each side of the highway were performed independently, using two or more sound level meters operated simultaneously. One meter was stationed at one of the three control measurement (CM) locations used on this site (see Figure 1). The other meter(s) were stationed at the site observation points, 5 to 10 m away from the houses. These site measurements were all performed with a microphone height of 1.2 m above ground. The control microphones were placed at 6.1 m above ground. Sound level measurements were of a 20 minute duration.

The after-construction sound level measurements were conducted using the same procedure, with all meters placed at the identical locations and heights as those used in the before surveys.

The barrier attenuation, adjusted for variations in highway traffic, was determined at each observation point using the following expression:

Barrier insertion loss at location $i = (L_{AC} - L_{Ai}) - (L_{BC} - L_{Bi})$
where:

L_{AC} = after-construction sound level measured at the control measurement location.

L_{Ai} = after-construction sound level measured at location i .

L_{BC} = before-construction sound level measured at the control measurement location.

L_{Bi} = before-construction sound level measured at location i .

The measured sound levels and insertion losses are presented in Table A1 of the Appendix. Standard MTC instrumentation was used.

3/ EVALUATION OF BARRIER REFLECTIONS

In addition to insertion loss measurements, measurements were conducted to determine the effect of the construction of the north-side barrier on the south-side sound levels.

The north-side barrier was constructed in July 1981 and the south-side in September 1981. Sound level measurements were performed opposite the north-side barrier before and after its construction to evaluate the possible increase in sound levels on the south side due to construction of the north-side barrier.

The results indicate no significant change in the south-side sound levels due to reflections. Sound levels were slightly lower, by about 2 dBA, after the construction of the north-side barrier, as can be seen in Table A1 for measurements 18BB versus 18AA.

This sound level difference can be attributed to a number of factors -- for example, the variation in traffic volumes that would not be accounted for by our control measurement.

4/ COMPARISON OF MEASURED AND PREDICTED SOUND LEVELS

Measured and predicted sound levels, before and after barrier construction, were compared in order to evaluate the performance of the two barrier materials (Evercrete and steel) and to further verify the accuracy of the BBN computerized Highway Traffic Noise Prediction Model [4]. This model has been modified by MTC [5] and is currently used to prepare acoustical design advice for construction of noise barriers.

The predicted sound levels were calculated using traffic volumes derived by dividing the 1980 AADT by 18. These traffic volumes were used in order to approximate the average traffic conditions experienced during the sound level measurements. Calculations for single barriers could be employed since no definite effect on barrier performance due to the opposing barrier was observed.

The difference between the before- and after-construction sound levels represents the reduction in sound levels due to barrier construction, i.e., the barrier insertion loss, ΔL_{eq} . Predicted insertion losses for the steel barrier were adjusted to account for sound transmission through the barrier material using the method developed by Jung [6]. The measured and predicted before sound levels and barrier insertion losses on the north and south sides are presented in Tables 1 and 2, respectively.

On the north side, the before-construction sound levels were, in general, over-predicted by an average of about 3.0 dBA. The typical barrier insertion loss measured at locations not shielded by houses was about 6.5 dBA. This compares favourably with the average predicted insertion loss of about 6.0 dBA. The BBN program over-predicted the insertion losses at locations shielded by one or two rows of houses by an average of about 2.0 dBA.

On the south side, a good (overall) agreement was obtained between the measured and predicted sound levels before and after barrier construction. The average measured and predicted sound levels before construction differed by about 0.5 dBA. The average discrepancy between the measured and predicted barrier insertion losses was also about 0.5 dBA.

The differences between the measured and predicted sound levels (and insertion losses) on both the north and south sides may be partially due to the estimated traffic volumes used in the calculations. Environmental factors (wind direction, temperature gradients, etc.) are not considered by the prediction program and could therefore contribute to this discrepancy. Also contributing were the varying measurement conditions caused by local community noise and environmental factors. These influences on the measured sound levels could not be adjusted for by control measurements.

The negative barrier insertion loss measured at location #12 on the north side does not necessarily mean a long-term increase in sound levels but is probably due to the above causes. The influence of factors such as ground cover, local community noise and environmental conditions on the measured sound levels are discussed in detail in References 2 and 7.

5/ COMPARISON OF THE ACOUSTICAL EFFECTIVENESS OF EVERCRETE AND STEEL BARRIER MATERIALS

Measured barrier insertion losses for similar Evercrete and steel barrier sections were compared with their predicted counterparts in order to evaluate the acoustical effectiveness of these materials. The predicted insertion losses for the steel barrier were adjusted for sound transmission loss through the barrier, as previously mentioned. The average insertion losses measured for the Evercrete and steel barriers were lower than predicted by about 0.1 dBA and 0.9 dBA, respectively. This would seem to indicate that Evercrete is acoustically more effective than steel at this site.

A t-test was performed to determine whether the differences between the measured and predicted insertion losses for the Evercrete and steel barriers were statistically significant. Results indicated that no significance could be attached to these differences. Therefore, no definite difference between the acoustical effectiveness of Evercrete and steel barrier materials could be determined.

6/ CONCLUSIONS

- 1/ The average measured barrier insertion loss in backyards adjacent to the barriers was approximately 6 to 8 dBA. The corresponding insertion loss for locations shielded by one or two rows of houses was approximately 2 to 3 dBA.
- 2/ The sound levels predicted by the BBN program were generally in agreement with the measured sound levels. There is, however, room for improvement, especially at locations adjacent to elevated portions of the highway (locations 6, 7, on the north side).
- 3/ There was no measured increase in sound levels on the south side due to sound reflections from the north-side barrier.
- 4/ No definite difference between the acoustical effectiveness of Evercrete and steel barrier materials could be determined due to the statistically insignificant differences in barrier performance.

7/ REFERENCES

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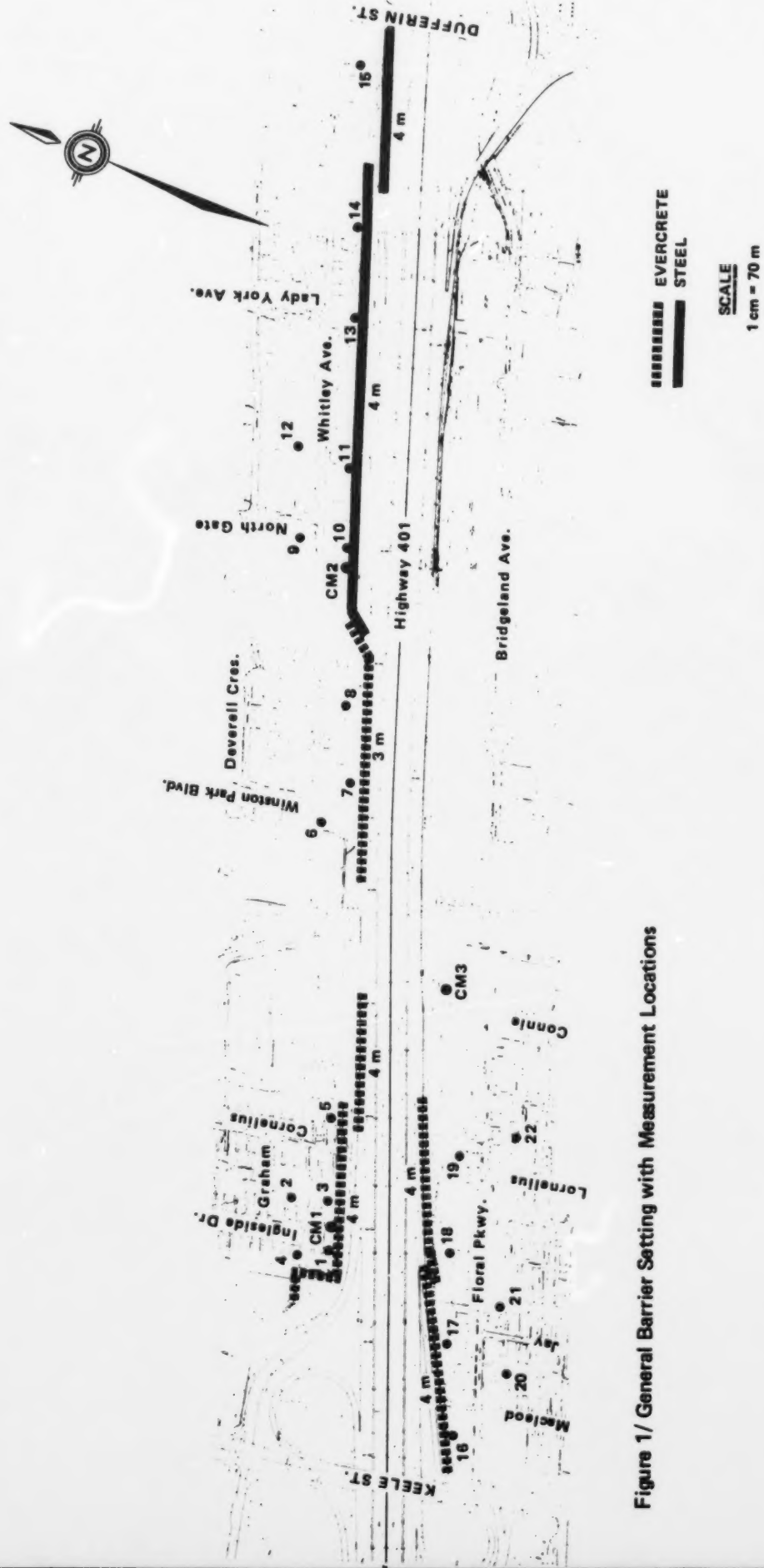


Figure 1/ General Barrier Setting with Measurement Locations

**Table 1/ Comparison of Measured and Predicted Sound Levels
(North Side)**

Measurement Location ¹	Sound Levels Before Construction L_{eq} , dBA		Barrier Insertion Loss ΔL_{eq} , dBA	
	Measured ²	Predicted	Measured ³	Predicted
1	2	3	4	5
Part A: Locations Not Shielded by Houses				
			1. 4 m Evercrete	
1	71.6	74.5	7.3	9.5
3	71.6	74.0	7.9	8.5
5	69.9	73.0	9.1	6.5
Average	71.0	73.8	8.1	8.2
			2. 3 m Evercrete	
6	68.0	72.0	6.1	2.5
7	70.5	73.5	7.1	3.0
8	71.6	72.5	7.3	3.5
Average	70.0	72.7	6.8	3.0
			3. 4 m Vertical Steel Panels⁴	
10	73.1	72.5	7.9	6.3
11	70.0	72.0	4.6	6.3
13	69.3	74.5	6.5	9.0
14	68.5	75.5	6.3	9.9
15	65.8	71.5	3.0	1.4
Average	69.3	73.2	5.7	6.6
Part B: Locations Shielded by One or Two Rows of Houses				
			1. 4 m Evercrete	
2	66.7	69.0	4.7	6.0
4	65.8	68.5	7.3	5.5
Average	66.3	68.8	6.0	5.8
			2. 4 m Vertical Steel Panels⁴	
9	63.6	68.0	0.4	3.4
12	58.1	62.5	-1.8+	2.4
Average	60.9	65.3	-0.7+	2.9

Notes:

- 1/ Measurement locations are shown in Figure 1. All measurements were taken 1.2 m above ground.
- 2/ The sound levels were obtained by averaging the measured sound levels (Table A1, Column 5) at each location.
- 3/ The measured insertion losses were taken from Table A1, Column 8 and have been adjusted for traffic variation using control measurements.
- 4/ The predicted insertion losses have been adjusted for degradation in attenuation due to sound transmission through the steel barrier.
- +/ Increase in sound level rather than attenuation.

**Table 2/ Comparison of Measured and Predicted Sound Levels
(South Side)**

Measurement Location ¹	Sound Levels Before Construction L_{eq} , dBA		Barrier Insertion Loss ΔL_{eq} , dBA	
	Measured ²	Predicted	Measured ³	Predicted
1	2	3	4	5

Part A: Locations Not Shielded by Houses

1. 4 m Evercrete				
16	73.0	73.5	6.0	6.0
17	69.7	70.5	5.5	4.0
18	71.1	74.0	3.5	7.5
19	71.8	70.0	5.9	4.5
Average	71.4	72.0	5.2	5.5

Part B: Locations Shielded by One or Two Rows of Houses

2. 4 m Evercrete				
20	57.7	59.0	3.7	1.0
21	63.4	61.5	1.1	2.5
22	60.9	60.5	1.7	2.5
Average	60.7	60.3	2.2	2.0

Notes:

- 1/ Measurement locations are shown in Figure 1. All measurements were taken 1.2 m above ground.
- 2/ The sound levels were obtained by averaging the measured sound levels (Table A1, Column 5) at each location.
- 3/ The measured insertion losses were taken from Table A1, Column 8 and have been adjusted for traffic variation using control measurements.

APPENDIX 1/ Measured Sound Levels, L_{eq}

Table A1/ Measured Sound Levels, L_{eq}

Location ¹ Number	L_{eq}					Measured Insertion Loss	
	Date	Time ²	Control Meas.	Site ³ Meas.	Difference 4-5	ΔL_{eq} ⁴	Average ΔL_{eq} ⁵
1	2	3	4	5	6	7	8
1 B ⁶	81-07-02	14:30	77	71.6	5.4		
1 B	81-07-02	15:08	78	71.8	6.2		
1 B	81-07-08	11:05	76	71.4	4.6		
1 A	81-08-31	15:00	77	65.4	11.6	6.2	
1 A	82-09-28	14:20	76.5	63.6	12.9	7.5	
1 A	82-09-28	15:30	76.6	63.1	13.5	8.1	7.3
2 B	81-07-02	14:30	77	66	11		
2 B	81-07-02	15:08	78	67.3	10.7		
2 A	81-09-01	13:00	78	63	15	4.1	
2 A	82-09-28	13:22	75.9	59.7	16.2	5.3	4.7
3 B	81-07-02	14:30	77	70.8	6.2		
3 B	81-07-02	15:08	78	72.3	5.7		
3 A	81-08-31	15:30	76	63.4	12.6	6.6	
3 A	82-09-28	15:00	76.7	61.5	15.2	9.2	7.9
4 B	81-07-03	11:30	76	65.8	10.2		
4 A	82-09-28	14:20	76.5	59.0	17.5	7.3	7.3

Table A1/ (Cont.)

Location ¹ Number			L _{eq}			Measured Insertion Loss	
	Date	Time ²	Control Meas.	Site ³ Meas.	Difference 4-5	ΔL_{eq} ⁴	Average ΔL_{eq} ⁵
1	2	3	4	5	6	7	8
5 B	81-07-03	11:30	76	71.1	4.9		
5 B	82-07-08	11:05	76	68.6	7.4		
5 A	82-09-01	15:00	76.7	61.4	15.3	9.1	9.1
6 B	81-06-29	15:00	78	69.0	9		
6 B	81-07-03	15:00	77	67.0	10		
6 A	82-10-25	14:45	77.9	62.3	15.6	6.1	6.1
7 B	81-06-29	14:30	77	71.0	6		
7 B	81-07-03	15:00	77	69.9	7.1		
7 A	82-06-24	14:45	76.5	62.3	14.2	7.6	
7 A	82-10-25	15:10	78.6	65.1	13.5	6.9	7.1
8 B	81-06-29	14:00	77	71.7	5.3		
8 B	81-07-03	15:00	77	71.4	5.6		
8 A	82-06-24	14:12	76.5	62.6	13.9	8.4	
8 A	82-08-26	15:35	77.9	65.7	12.2	6.7	
8 A	82-10-25	15:25	78.4	66.1	12.3	6.8	7.3

Table A1/ (Cont.)

Location Number			L_{eq}			Measured Insertion Loss	
	Date	Time ²	Control Meas.	Site ³ Meas.	Difference 4-5	ΔL_{eq} ⁴	Average ΔL_{eq} ⁵
1	2	3	4	5	6	7	8
9 B ⁶	81-06-30	10:50	77	61.4	15.6		
9 B	81-07-03	14:15	77	65.8	11.2		
9 A	82-05-31	15:40	77.8	65.8	12.0	-1.4+	
9 A	82-06-24	15:15	76.7	60.6	16.1	2.7	
9 A	82-08-26	14:33	77.5	64.3	13.2	-0.2+	0.4
10 B	81-06-29	15:45	77	73.6	3.4		
10 B	81-07-03	14:15	77	72.6	4.4		
10 A	82-05-31	11:45	76.6	64.8	11.8	7.9	
10 A	82-06-24	15:15	76.7	65.0	11.7	7.8	7.9
11 B	81-06-30	10:50	77	70.0	7		
11 A	82-05-31	12:15	77.3	64.9	12.4	5.4	
11 A	82-08-26	14:00	77.7	66.9	10.8	3.8	4.6
12 B	81-07-03	14:15	77	58.1	18.9		
12 A	82-05-31	15:10	78.0	61.2	16.8	-2.1+	
12 A	82-08-26	14:00	78.0	60.5	17.5	-1.4+	-1.8+

Table A1/ (Cont.)

Location ¹ Number			L _{eq}			Measured Insertion Loss	
	Date	Time ²	Control Meas.	Site ³ Meas.	Difference 4-5	ΔL_{eq} ⁴	Average ⁵ ΔL_{eq}
1	2	3	4	5	6	7	8
13 B ⁶	81-06-30	11:15	76	69.5	6.5		
13 B	81-07-07	11:45	77	69.1	7.9		
13 A	82-05-31	14:12	77.7	64.0	13.7	6.5	6.5
14 B	81-06-30	14:30	77	68.6	8.4		
14 B	81-07-07	11:45	77	68.4	8.6		
14 A	82-05-31	14:42	77.9	64.7	13.2	4.7	
14 A	82-06-16	14:30	79.2	62.8	16.4	7.9	6.3
15 B	81-06-30	14:30	77	65.2	11.8		
15 B	82-07-07	11:45	77	66.3	10.7		
15 A	82-06-24	13:35	76.2	61.9	14.3	3.0	3.0
16 B	81-08-05	15:30	74.0	73	1.0		
16 A	82-09-09	14:30	69.4	62.4	7.0	6.0	6.0
17 B	81-08-05	15:06	74.4	70.8	3.6		
17 B	81-08-06	13:30	71.4	68.6	2.8		
17 A	82-08-27	10:45	70.9	63.4	7.5	4.3	
17 A	82-09-08	13:55	70.1	60.2	9.9	6.7	5.5

Table A1/ (Cont.)

Location ¹ Number	L _{eq}					Measured Insertion Loss	
	Date	Time ²	Control Meas.	Site ³ Meas.	Difference 4-5	ΔL_{eq} ⁴	Average ΔL_{eq} ⁵
1	2	3	4	5	6	7	8
18 BB ⁶	81-07-08	11:05	76	72.9	3.1		
18 BB	81-07-10	11:10	76	72.8	3.2		
18 AA	81-09-01	15:30	76	68.8	7.2	4.0	
18 AA	81-09-21	11:50	74.9	71.2	3.7	0.5	2.3
18 B	81-08-05	14:30	74.7	72.5	2.2		
18 B	81-08-06	13:30	71.4	69.6	1.8		
18 A	82-08-27	11:12	71.6	66.1	5.5	3.5	3.5
19 B	81-08-05	14:00	74.6	71.4	3.2		
19 B	81-08-06	15:30	74.0	72.1	1.9		
19 A	82-08-27	11:40	71.4	64.2	7.2	4.6	
19 A	81-09-09	14:00	69.3	59.5	9.8	7.2	5.9
20 B	81-08-05	15:00	74.4	57.7	16.7		
20 A	82-09-08	14:30	69.9	49.5	20.4	3.7	3.7
21 B	81-08-05	14:30	74.9	63.4	11.5		
21 A	82-09-08	13:25	70.2	58.9	11.3		
21 A	82-09-29	13:55	71.2	58.7	12.5	1.1	1.1
22 B	81-08-05	14:00	74.6	60.9	13.7		
22 A	82-09-29	13:20	71.9	56.5	15.4	1.7	1.7

Notes:

- 1/ Measurement locations are shown in Figure 1.
- 2/ Starting time of measurement. All measurements were of 20 minutes duration.
- 3/ The measured sound levels were unadjusted for road traffic and other variations.
- 4/ The barrier insertion losses were adjusted for traffic and other variations using control measurements. The barrier insertion losses at each location were obtained by subtracting the average of the results given in Column 6 for the before series (B) from the results given in Column 6 for the after series (A).
- 5/ The average barrier insertion losses from Column 7.
- 6/ Measurements taken:
 - B -- Before barrier was constructed.
 - A -- After barrier was constructed.
 - BB -- Before either north- or south-side barrier was constructed.
 - AA -- After the north-side barrier was constructed, but before the south-side barrier was constructed.
 - + -- Increase in sound level rather than attenuation.